Globalization, Outsourcing and Modularity in the Auto Industry

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Abstract

The paper discusses the relationship between globalization, modularization and outsourcing in the auto industry. It maintains that modularity is a broad concept, applicable and applied to product design, manufacturing and organization and that modularization is a strategy aimed at reducing the complexity stemming from globalization of products, markets and production. However, modularity has only recently moved its first steps in auto design and manufacturing and is a vaguely defined and ambiguously used concept in the auto industry.

The paper suggests that, in the auto industry, economic and institutional factors related to globalization represent key drivers of modularization as much as technology. Besides, as the auto industry globalize, modularization and outsourcing, though remaining conceptually distinct, tend to become, in practice, increasingly inseparable.

1. Globalization and the new contracting structure of the auto industry

Globalization is having a major impact on the automotive industry.

This international re-location of auto demand is generating an international re-location of auto manufacturing. This happened for a number of reasons.

Firstly, models produced and marketed in North America, Europe and Japan do not always fit emerging markets' customers needs. Secondly, governments of emerging market countries put constraints and incentives on auto trade and manufacturing in order to hinder imports and favor foreign direct investment from large multinational companies. Thirdly, locating operations nearby the target market represents an advantage in terms of marketing, sales and logistics. Fourthly, cross-country cost differentials (especially labor cost), are often so high that they can themselves represent a reason why to locate production abroad.

Within this new framework OEMs and suppliers have re-designed their relationships towards a new situation where: a) suppliers play a larger role in terms of parts' design, technology development and, sometimes, even assembly; and b) OEMs tend to focus their activities, narrowing the scope of the operations they carry on.

More generally, assemblers have employed a series of measures to lower the minimum scale of vehicle assembly plant (Florida and Sturgeon, 1999) in order to reduce investment risk, respond more flexibly to volume changes, speed up models turnover, facilitate equipment upgrading, minimize job impact and social cost in case of crisis. Financial considerations are especially critical given the enormous amount of money required by foreign direct investment strategies and the uncertainty of their rate of return and payback time.

On the whole, globalization has sharpened competition and contributed to shaping a new international division of labor in the auto industry, one where suppliers can achieve economies of scale and of specialization and OEMs can reduce the organizational costs stemming from the complexity underlying international strategies. At the same time, new (especially Internet related) technologies are facilitating knowledge codification (Nonaka and Takeuchi, 1995), reductions in information costs, and evolution towards mass customization and build to order (Helper and Mac Duffie, 2000). These technologies tend to lower the transaction-specific nature of information, knowledge and capabilities, reducing coordination costs for market-type relationships.

Therefore, in the new global auto industry, there have been (and, to a certain extent, there still are) incentives to transfer component design/manufacturing responsibility to suppliers. This has entailed, from the OEM perspective, more outsourcing, and determined a power shift in favor of suppliers (Fine, 1998), as they continue to grow and consolidate in a wave of M&As operations.

But, despite this moving assets off the books to suppliers, designing and managing an international supply chain *remains* a complex task for OEMs and suppliers. Trying to use e-business tools (B2C and B2B) across the supply chain, facing the different national and regional institutional settings, seeking cost savings in low wage countries and minimizing investment risk, not only imply a different partition of tasks and rights across the supply chain, but also impact on product architecture feeding back into greater product design/technological complexity (Sako and Murray, 1999; Fujimoto and Takeishi, 2001).

Modularization is one possible way to address this issue and reduce complexity. Modularization means that, in the future, vehicles will probably result from the integration of a series of self-contained functional units with standardized interfaces within one or more standardized product architectures, units conceived, manufactured or supplied, and assembled as autonomous "modules" (Helper, MacDuffie, Takeishi and Warburton, 1999).

At the moment, the term “modularity” itself is still somewhat vague in the auto industry. Practitioners (but, to some extent also scholars) are using it to cover a wide variety of practices, whose common elements (and relationship to any core definition) are relatively few. This relates to the fact that a) modularity is a broad concept that can refer to a variety of different systems and variables (product design, manufacturing, work organization, inter-firm relationships, etc.) (Schilling, 2000); b) modularization has only recently moved its first steps in the auto industry; and c) the drivers and purposes of modularization are diverse across regions and companies.

2. Working out the “modularity” concept in the auto industry

2.1. Modularity in design

Referring to modularity in product design, Baldwin and Clark (1997, p.86) assert that the decomposition of a system into modules requires three elements:

- An architecture that specifies what modules will be part of the system and what their functions will be.
- Interfaces that describe in detail how the modules will interact, including how they fit together and communicate.
- Standards that test a module's conformity to design rules and measure the module's performance relative to other modules.

Modularity-in-design is therefore defined as choosing the design boundaries of a product and of its components so that design features and tasks are interdependent within and independent across modules (Huang and Kusiak, 1998; Sako and Murray, 1999). In the auto industry, very few companies have advanced very far in the modularization of design and, on the whole, the practices that reflect a relationship to this definition are relatively few. This situation reflects the fact that, both for functional/technological and historical reasons, the current dominant product architecture (Ulrich, 1995) for autos is integral rather than modular, i.e. auto parts present little cross-product/cross-firm standardization.

Nonetheless, OEMs and suppliers have recently been working on this side, with encouraging results. For example, within the FIAT-GM powertrain Joint Venture, the two partners have pursued a strategy of common “architectures”: this means that Fiat and GM have chosen to work, with different projects for different market segments, on a highly modular car underbody capable of absorbing length and width variation and different front-ends and rear structures, in order to achieve differentiation on vehicles to the full satisfaction of the need to customize brands (Camuffo and Volpato, 2001).

This has facilitated the definition of common parts because they work on sub-systems rather than on highly complex and very rigid systems such as the platform itself. GM and Fiat are jointly working on different vehicle segments seeking the highest possible unification on all architectures, but developing specific solutions for the individual brands, aimed at obtaining the desired performance in each brand.

Examples of differentiation can stem from the use of different:

- types of suspensions, and within the same suspension from the different tuning of some elements or from the presence of non common subsystems studied to allow different performances;
- engine ranges and different coupling with gearboxes and transmissions will allow to guarantee in some cases the features of sportiness and in other cases those of comfort;
- types of transmission (front or four wheel drive);
- sizes in terms of length and width.

Relevant efforts at modular design have been made also by suppliers, both North American and Europeans, like French suppliers Faurecia and Sommer Allibert Industrie which have invested heavily on design and manufacturing capability for cockpit and door modules (Murphy, 1999; Farhi, 1998).

An interesting example is also Denso International America, that has recently started making integrated air-fuel modules, combining vehicle parts that allow fuel and air to flow to the engine compartment. The module integrates the air intake manifold, the air induction system, fuel injectors, throttle body, wire harnesses and sensors into one unit. Previously, Denso made most of those parts, except for the air intake manifold. Now it coordinates the activities of 15 outside suppliers. The modular piece has reduced weight from 28.6 pounds to 19.8 pounds for the total system and simplified assembly by eliminating fasteners. The parts are molded to the manifold body instead of connected mechanically. Among Denso competitors, Siemens Automotive, Mann & Hummel GmbH and Dana Corp have also recently worked on some form of an integrated air-fuel module (Pryweller, 1999).

Johnson Controls Inc. has developed the "Core Product Portfolio Program", a program that uses the same components for interior parts, such as seats, to cut costs and speed product development. Under this modular design, which has enabled to reduce costs of an interior by 10%, the seats in a luxury car and an entry-level car could use many of the same frame pieces but look and feel completely different. The key element of modularity in design is represented, even in this case, by the support structures that use a standardized connection interface. In a seat, for example, the areas where the metal seat frame connects are all the same. If Johnson Controls needs to make the seat wider or the seat back taller, it can do so by specifying longer frame sections between the connections. Also, the seat frames are designed to allow other functions, such as mechanical or power adjusters or heating and cooling devices, to snap into place with the same connections. The ultimate goal is to turn basic components such as the seat frame into commodities. Johnson Controls is working on 6 interior areas that have potential for using modular components: seats, overhead systems, cockpit/instrument panel electronics, trim and garnish, carpeting and floor units (Jewett, 2002).

Summarizing, in the auto industry there is not, at the moment, a modular product architecture. Rather, OEMs and large suppliers anre experimenting with an incremental approach. There is wide cross-company variations on module boundaries and no industry understanding or standard on how many modules a vehicle consists of.

2.2. Modularity in manufacturing

Modularity-in-production means, instead, choosing product design and plant design boundaries to facilitate production to meet product variety, production flow, cost and quality requirements. Besides, the industry jargon (but also some literature) widens this definition and refers to modular manufacturing also as designing manufacturing and assembly in order to reduce the complexity in the main process by means of sub-assembly, pre-fitment testing of modules, and transferring some of these activities to suppliers (He and Kusiak, 1997; Kinutani, 1997; Fujimoto and Takeishi, 2001).

Apart from the early experiments at GM-Opel and Fiat in the late '80s, in the last five years GM, Ford, Daimler-Chrysler, Mercedes-Benz, Volkswagen and Fiat have experimented with modular assembly plants overseas.

Volkswagen was the first OEM to apply modularity concepts extensively and on an international basis, specifically at its plants in Resende (Brazil), Boleslav (Czech Republic) and Mosel (former East Germany) (Marx and others, 1997).

Notwithstanding the controversial results of these experiments, other automakers have continued to study modular manufacturing, developing production systems in which a) suppliers design, build and deliver major subassemblies, such as a complete front end, a cockpit, a door; and b) OEMs minimize investment and can focus on engineering vehicles, work on quality, and serve customers. The key idea is that having modules made on separate and/or parallel production lines by suppliers makes it easier to change and improve those components, and therefore less likely to cause plant-wide breakdowns. General Motors Corp. and Ford Motor Co. have built modular-style assembly plants in Brazil's southernmost state of Rio Grande do Sul. The Ford plant produces subcompact cars. 12-15 primary suppliers deliver subassemblies from their own factories nearby. The large-scale modular GM ``Blue Macaw'' plant, located in Gravatai, is probably the furthest along in harnessing modular assembly. There, 17 suppliers assemble modules that snap together at the rate of 100,000 Chevrolet Celta subcompacts per year (Welch, 2001).

In July 1998 Chrysler set up a completely new pick-up truck (the Dakota) factory in Curitiba in the state of Paranà, south of San Paolo. The unique feature of this plant is the outsourcing of the "rolling chassis" to Dana; a US, Ohio based supplier located a few kilometers from the assembly factory. The latter is therefore smaller than usual, allowing Chrysler to reduce its own expenses by lowering stock levels and sharing risks (and presumably profits and losses) with its suppliers (Couretas, 1999). The "rolling chassis," it's a major module complete with tires, springs, shock absorbers, fuel tank, brakes and steering components. The modular method even goes back to the subsuppliers, who themselves deliver submodules to Dana for assembling (Jones, 2000).

In Ramos Arizpe, Mexico, General Motors has recently used modular assembly for the new Pontiac Aztek. Modules - pre-assembled groups of parts - account for about 30 percent of the vehicle and are shipped to the plant and bolted together.

Another clear example is the arrangement between Delphi Automotive Systems Corp. and Mercedes-Benz U.S. International Inc. in Vance, Ala. Ten minutes away from the OEM plant, Delphi's Cottondale plant thumps out 130-pound cockpits every 2.8 minutes for the Mclass assembly line. Two hours after being produced, the modules are fitted into vehicles.

The Delphi plant also produces about 500 modules every week for shipment to Mercedes' other M-class line at Steyr-Daimler-Puch, 4,000 miles away in Graz, Austria. The cockpits appear there six weeks later in sequenced-in-line form. Delphi's modular approach origined in early 1990s, when the company took over a small section of a Mercedes assembly line in Germany to demonstrate its manufacturing capability. Assembling cockpits for the E class let Delphi prove it could harmonize with Mercedes. When Mercedes planned its U.S. plant in 1994, it chose Delphi to be the cockpit's system integrator and modular supplier (Moran, 2000).

The financial crises of the late 1990s in the Far East, Mercosur and Russia have added to the growing need to reduce the risks associated with the huge investment required to set up production plants. As a result, the trend toward modularization *and* outsourcing of support and direct activities has continued and will probably continue in the future.

Some OEMs have implemented modular manufacturing in their home country plants, too. General Motors has been most outspoken in its plans to pursue modular manufacturing in North American plants. In 1999, General Motors announced a dramatic plan ("Project Yellowstone") to change its manufacturing methods and potentially achieve enormous cost savings. The project would consist of new modular factories, where suppliers would deliver finished sections--from doors and dashboards to fully assembled chassis and suspension systems--that are traditionally assembled at the factory. But this project was stopped by the United Auto Workers and GM, leery of a strike, retreated (Smith, 1999; Jones, 2000). Only recently GM was able to move towards slimmed-down plants (like, for instance, the new Cadillac one in Lansing, Mich.) by a) avoiding any reference to modular production (Miller, 2000), b) pushing for on-site supplier presence (like it did in its new Opel plant in Ruesselsheim, Germany), c) having the right UAW local, willing to compromise to get the plant built, d) pushing shop-floor efficiencies, d) improving parts delivery, e) picking the right product and f) picking the right workers, willing to work in teams and take on responsibilities (Guildford, 2002).

Ford Motor Co., DaimlerChrysler AG and others are also adopting modular production methods in their North American and European operations.

DaimlerChrysler used to assemble instrument panels in its own US plant. Recently, it has farmed out the ``cockpit" work for the Jeep Liberty models built in Toledo, Ohio. Six nearby suppliers, led by Johnson Controls Inc., assemble the plastic dashboard, mount the instruments, and deliver plug-in systems (Welch, 2001).

The most famous example is probably the MCC plant in Hambach (France). MCC is a joint venture between Mercedes Benz and Swatch (Swiss watch producer), that assembles a two-seater "minicar" (named Smart). A small group of suppliers, defined as "system partners", located nearby the MCC plant, build and deliver complete modules like doors and cockpits directly to MCC final assembly line (Fujimoto and Takeishi, 2001).

Summarizing, in auto manufacturing globalization seems to have triggered a trend toward a change in the dominant configuration of assembly plants and supply relationships ("production architecture"), from the traditional one, that was substantially closed and nonmodular, to a new one, where:

a) production systems are broken down into quasi-independent subsystems ("modules"), which are likely to correspond to design modules (a door, a front end, a cockpit, etc.), and become more standardized initially across plants of the same OEM, and, possibly in the future, across companies, and across OEMs-suppliers relationships; b) plant size tend to be lower than in the past and a handful of "full service" suppliers design, build and deliver larger sets of components either from within the OEM plant (modular consortium) or from satellite plants (supplier park).

2.3. Modularity in organization

Most researchers seem to converge on the idea that there is a relationship between product architecture and organizational architecture (Sanchez and Mahoney, 1996; Langlois, 1999; Baldwin and Clark, 2000; Helper and MacDuffie, 2000; Koppl and Langlois, 2001; Fujimoto and Takeishi, 2001). However, it is not yet clear how modularization of design and production relates to intra-firm and inter-firm organizational design.

As regards internal organizational design, for example, some research (Tsukune and others, 1993; Rogers and Bottaci, 1997) refers to modular production as designing manufacturing processes in order to flexibly reprogram machining, welding and assembly systems in a timely and cost-effective manner to quickly adjust production output to market conditions. Plants are intended to have greater versatility for future engine or car body changes without extensive retooling or large capital investment. Layout and equipment can be standardized in elementary bundles. In many cases, different plants of the same OEM tend to follow a common technological and organizational template conceived and developed in a "pilot" plant in order to take advantage of a) economies of scale and learning effects, and b) of cost effective, timely and easier plant start-ups. From this standpoint the concept of modularity takes up a typical organizational meaning and mingles with those of standardization, scalability and replication. It means that the typical operating processes of a plant are broken down in "modular organizational units" and designed in terms of self-contained units defined as production modules. Each "organizational module" can correspond to a "design module", is characterized by certain equipment and degree of automation (with possible variants and adaptations), follows a given organizational scheme (in terms of staffing, teamwork, number of hierarchical layers, direct/indirect workers ratio, training and performance appraisal procedures, compensation policies, etc.) and is designed to meet required production capacity. A major consequence of this aspect of modularity is the cross-plant "replication" of work organization, human resource management systems, logistics and supplier relationships, in addition to production equipment. Thus, if several plants (even belonging to different OEMs) use the same technology supplier (say for body welding or assembly equipment), and component suppliers are the same for at least part of the process, then working by modules also means repeating in different plants (and, possibly, different companies) an established set of relationships, working methods, standard operating procedures, rules, documentation and communication devices.

With modularity in organization, organizational processes, governance structures and contracting procedures could be fine tuned and replicated first of all within firms, i.e. across plants of the same firm in different countries, then between a given OEM and its suppliers, and, eventually, even across firms and supply chains. Especially if the internet technologies will openly support the OEMs-suppliers relationships, these systems of rules and incentives could possibly become one or more organizational standards in the auto industry, facilitating risk sharing in multiple customers/multiple suppliers relationships and allowing transaction cost reductions across the whole supply chain.

Therefore, as regards intra-firm and inter-firm organizational design, an analogical application of modularity to organization, implies that, in general, an organization tend to be modular when interdependence is low between and high within each “organizational” module, guideline that follows the classical principle proposed by Thompson (1967).

It is worth noting that, in the extreme situation in which, for technological reasons, interdependence within is maximum (extremely high) and interdependence between is minimum (extremely low), the standard interface that allows the “organizational modules” to coordinate with one another without communicating large volumes of information is the price system (Langlois, 1999).

The fact that market-type relationships mirror, from a social institutions/organizational perspective, the theoretical situation of perfect modularity in design and production, poses the question of the relationship between outsourcing and modularity.

3. Outsourcing and modularity

The previous section showed that, compared with other sectors, modularization has only recently moved its first steps in the auto industry (Lynch, 1999). Only in the last few years OEMs and suppliers have worked on the idea that an automobile is a complex system that can be broken up into discrete pieces (modules) -which can then communicate with one another through standardized interfaces within a standardized architecture- and that given types and amount of knowledge can be encapsulated within such modules.

Also the fact that, in the auto industry, modularity is a vaguely defined and ambiguously used concept has had a number of effects. For example, while plenty of academic work has concentrated on modular design (Baldwin and Clark, 2000) studying practices from such industries as computers and software, few carmakers have extensively experimented with modularity in product development.

Practitioners are more familiar with modular manufacturing, but, in many cases, OEMs and suppliers use this as a synonym of outsourcing, generating confusion. In fact, outsourcing of various, even direct assembly activities can take place even though there is no modularity in design, sourcing or manufacturing (typical European and US practice). By reverse, modularization can exist without outsourcing (Helper and others, 1999) (typical Japanese practice (Fujimoto and Takeishi, 2001)). In fact, in japan only a few suppliers, such as Denso Corp. and Ichikoh Industries Ltd., have gone forward with modules. The others probably feel they don't have the breadth of product line and managerial capabilities needed to design, produce and deliver entire systems. This relates also to Japanese cultural aversion to M&As, as well as relatively limited exposure to U.S. and European markets (Treece, 1998). Moreover, Toyota and Honda feel modularity, turning modules into "balck-box parts", would transfer too much power to suppliers.

On the whole, however, outsourcing, task partitioning, standardization and knowledge encapsulation, although conceptually distinct, remain strictly intertwined in practice, since the evidence coming from the field shows that, especially within global strategies, modularization and outsourcing are becoming increasingly inseparable, that is suppliers increasingly tend to design, produce (either at their own facilities or somewhere else) and deliver complete modules with standardized interfaces within a given product architecture. The main consequence of this trend is that modularity *and* outsourcing are related to a major transformation of supply chains and organizational forms (Sako and Warburton, 1999).

This relationship between the process of task partitioning between OEMs and suppliers and the process of standardization and "knowledge encapsulation", that is typical of modularization, give partial support to what maintained by Sanchez and Mahoney (1996 and 1997), who contend that, while nonmodular products lead to or are best produced by nonmodular organizations, modular products call for modular organizations. Also Langlois (1999) asserts that traditional, bureaucratic firms' organization reflect nonmodular structures, that is a partition of property rights, decision rights, alienation rights, and residual claim of income rights alternative to an atomistic modularization in which all four coincide. Therefore, as in the past (following lean production principles) auto manufacturing moved from the traditional bureaucratic/hierarchical/vertically integrated organization to more flexible network organizations (the Toyota system, the OEMs-suppliers partnership, etc.), in the future, especially if the internet (B2C and B2B) enables mass customization and build to order, it will probably move on to a new model, similar to the "Dell-direct" model in the computer industry (Helper and MacDuffie, 2000), taking the form of turnkey networks (Sturgeon, 1997).

Nonetheless, if it is true that product architecture impacts on organizational architecture, it is also true the reverse. In other words, modularity is not only a cause, but also an effect; modularity, namely modular design, *does not purely and simply determine* organizational structures, but, to a certain extent, it is also a consequence of intra-firm organizational design choices and inter-firm boundary definition strategies, which, in turn, can derive from labor markets or capital markets considerations (Sako and Murray, 1999).

Within this context, globalization plays an increasingly crucial role. As pointed out in section one, since it contributes shaping the international division of labor between OEMs and suppliers, it also has an impact on modularization.

In fact, international rules (trade barriers, local contents, etc.), regional/national institutions, and cross-country cost differentials impact on the transfer of component design/manufacturing responsibility to suppliers and, as a consequence, on the degree of decomposability and information partitioning into visible design rules of new and existing products (Schilling, 2000).

The recent debate on the GM-Yellowstone project and on how GM modular operation at its "Blue Macaw" plant in Gravatai, Brazil could impact on GM North American operations demonstrate this relationship between globalziation, outsourcing and modualrization. In fact, modular manufacturing has at least the potential aeefct of trimming production expenses by shifting work to factories, namely non-union, with lower labor costs (Welch, 2001).

Summarizing, despite the ambiguous terminology, the few experiences realized in the auto industry confirm the link between globalization, outsourcing and modularization, and show that modularization of auto design and manufacturing tend to be a typical feature of international strategies, especially at OEM greenfield plants in emerging regions (Sako and Warburton, 1999).

4. Implications

On the whole, the previous sections confirm that there is a relationship between the new international division of labor across the auto industry (stemming from a different task partitioning between OEMs and suppliers) and the process of standardization and "knowledge encapsulation" that is typical of modularization.

The embryonic applications of modularity in design, manufacturing and organization can be used to map out future developments and transformations in the contracting structure of the auto industry.

For example, if the internet (B2C and B2B) enables mass customization and build to order, it is likely that the dominant product architecture for autos will become more modular and open (cross-product and cross-firm standardization of components with standardized interfaces), and the transition toward the "turnkey network" (Sturgeon, 1999) or "Dell-direct" (Helper and MacDuffie, 2000) model, almost automatic. But even though the dominant product architecture for autos remains nonmodular, some major transformation is likely to take place. More and more frequently, global suppliers will be able and willing to design modules from proprietary knowledge, manufacturing and supplying them, from their international plants, to multiple customers (OEMs) that want or have to share, at least in part, an increasingly similar product architecture. A good example of this is represented by the recent initiatives of the GM-Fiat powertrain and worldwide purchasing joint ventures. These are intended to develop common, cross-product and cross-firm power trains and components, at the moment for FIAT and GM, but, in the future, also for other OEMs.

From this standpoint, outsourcing and modularity, though increasingly inseparable and overlapped in practice, remain conceptually distinct; for example, OEMs will be interested in transferring to independent suppliers the information required to design and/or produce a given module; but, at the same time, they will be interested also in maintaining, protecting and defending all that knowledge (and, increasingly, it will be architectural knowledge) that represents a distinctive asset (MacDuffie and Helper, 1999), or where there area advantages related to cross-country/cross-firm factor price differentiation (capital and labor market conditions) (Sako and Murray, 1999). Hence, the contracts' format and the related sets of rules and incentives, necessary to design and manage the relationships with suppliers of engineering, components and services, could be standardized not only worldwide across plants (i.e. within the same OEM-supplier relationship), but also across supply chains (multiple OEM-supplier relationships).

For some time the term “modularity” will still remain ambiguous in the auto industry, and practitioners (but, to some extent also scholars) will use it to cover a wide variety of practices. But this reflects the fact that a) modularization is a complex, slow and controversial process (for example because it will negatively affect OEMs' capability to differentiate and characterize their vehicles’ and brand identity *vis a vis* competitors); b) modularization can refer to different systems and variables (product design, technology, manufacturing equipment, work organization, etc.); and c) auto design and manufacturing is intrinsically more complex than other products like, for example, software or computers (e.g. in terms of logistics, safety and environmental issues).

On the whole, this paper confirms that the wave of transformation that has reshaped other, "faster clockspeed" industries (Fine, 1998), is tremendously changing also the contracting structure of the auto industry, and that globalization, together with information and communication technologies, is challenging OEMs' and suppliers' existing strategies and structures.

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